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Pedestrian Detection

Michael Del Rose, Philip Frederick

Intelligent Systems Directorate, U.S. Army Tank Automotive Research Development and Engineering Center (TARDEC), Warren, MI, 48397-5000

Abstract
Pedestrian detection has been an active topic for several years. Many types of sensors and algorithms have been explored with varying levels of success. Currently, the pedestrian detection program within the Intelligent System TARDEC Technology area concentrates on stereo vision systems: stereo gray scale, stereo color, and stereo infrared. Both human detection from a single framed, stereo-paired image and tracking using a sequence of stereo-paired images are investigated. This paper will discuss the current and future state of these activities.

1. Introduction
Pedestrian detection is an important field of research. Autonomous and semi-autonomous vehicles need to identify people while traversing through the terrain in order to take appropriate actions to avoid them. Driver awareness systems, like those proposed by the Department of Transportation Intelligent Transportation Systems Division, need the ability to alert drivers of potential problems when driving through urban areas. Additionally, the Department of Defense needs pedestrian detection for path following and mule operations on robotic vehicles.

In this paper, the focus is on pedestrian detection and its use in robotic vehicles. Section 2 discusses the types of pedestrian detection systems that are commonly found in most literature. Section 3 discusses the specifics of vision based pedestrian detection. Vision based pedestrian detection is the focus of the work performed at Intelligent Systems Human Intent and Analysis Lab (HID Lab). The HID Lab projects are discussed in section 4. Section 5 concludes the discussion and section 6 lists references.

2. Pedestrian Detection Systems
The research area of pedestrian detection is very large. There are many different approaches to this problem. Some use LADAR or laser scanners to retrieve a 3D map of the terrain and detect pedestrians [1,2,3,4], another uses ultrasonic sensors to determine the reflection of pedestrians [5]. Radar is also popular for detecting pedestrians similar to ultrasonic sensors; by measuring the reflection of possible

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targets and determining if they are pedestrians or not [6,7].

A natural choice for a sensor is vision because it is based on how people perceive pedestrians. Within the area of computer vision there are infrared vision, monocular vision, and stereo vision processes. Each vision system has its own advantages and disadvantages. Infrared systems [8,9,10,11] are not as sensitive to lighting conditions when compared to other visual sensors. However, they are more expensive and the image quality is not as good. Monocular vision systems [12,13,21] are cheap and require lower processing power, but they perform poorly at providing range data and are more sensitive to color and lighting. Stereo vision systems [14,15,16,17,18,19,20] have the advantage of being able to view potential objects from two points of view. They are also used to detect dispersion (or depth) of objects. The drawbacks of stereo vision systems are that they require more processing time and are sensitive to color and lighting conditions.

3. Vision Based Pedestrian Detection Systems

Vision based pedestrian detection is a difficult problem because of processing speed, robustness of vision sensor's algorithms, and a lack of maturity in computational intelligent systems to recognize everyday object. For the Department of Defense, specifically TARDEC, vision based detection is important for non-evasive pedestrian detection systems in the areas of path following, mule operations, surveillance, and driver awareness. The problem increases in difficulty when considering the movement of the sensors, uncontrolled outdoor environments, and variations in pedestrian's appearance and pose. There are many types of algorithms that try to address these problems.

Motion based systems are used to detect pedestrians from image sequences. They take into account the temporal information to detect periodic features of human movement [15,17,18]. This technique reduces the number of false positives from other methods, but requires a lead time of images, which causes a delay in the detection. Another drawback is that it is unlikely to detect people standing or making unusual movements (like jumping).

Template based systems [14,16,20] can be used on single frames so they do not require a lead time or movement of a pedestrian. These systems match pre-defined pedestrian typical shapes (generally) with the image to recognize people in the picture. The problem with most of these procedures is that they have difficulty in detecting variations in a pedestrian's appearance or pose.

One other common method is to detect body parts of person, then put them together in a logical form to determine the confidence of the target being a person or not [19,21]. This requires a lot of processing, but is good at detecting occluded people. However, many false positives can occur due to matching potential body parts of things unrelated.

4. Intelligent System's Pedestrian Detection Program

The pedestrian detection programs in the Intelligent Systems TARDEC Technology Area look at several different types of algorithms to detect people. The main focus is on visual and infrared sensor based pedestrian detection systems. Each algorithm is modeled for the environment it will be used in, from driver awareness systems to pedestrian following autonomous systems. Below is a description of the types of pedestrian detection projects currently being researched by the HID Lab.

Human Localization Using Gray Scale Stereo Imagery.

This programs main purpose is two-fold. First it is used to detect humans from a single, stereo-paired image and alert the driver of the person's location with respect to the cameras; second it provides an autonomous robotic system the location of people in the scene. It uses gray scale intensity mapping with depth information from the stereo cameras to single out possible people. Then it removes most all false positives by doing a head-shoulders template check of the candidates. Finally, it sends (or displays) the pedestrian location. The head shoulders check is the only template matching done on this algorithm and it is used mainly to decrease the false positives.

Human Localization Using Infrared Stereo Imagery.

This program will be used in conjunction with the Human Localization using gray scale imagery to improve the performance of pedestrian detection systems. Alone, it works well in day or night as long as the outside temperature is below 85 degrees. First, it views the higher intensity areas and computes the distance of the areas in both left and right camera views. Any non-matched items are removed. Then it populates the remaining regions based on distance from the camera and, correlates this information with typical human length/width ratios. Final processing involves a head-shoulders template match in the regions of interest and removes candidates without one.

Combining the infrared stereo imagery and the gray scale stereo imagery will provide a pedestrian detection system that relies on several types of data. The information from each of the processes will be combined intelligently to determine locations of humans. The goal is to choose the best pieces of information from both gray scale and infrared processing algorithms based on the vehicles current environmental conditions.

Color Stereo Pedestrian Detection.

This project's main goal is to increase the current pedestrian detection systems by adding intelligent techniques to color processing. The color image is processed to cluster different shades of colors and distances from the camera. The image is then matched against templates for body parts (arms, legs, torsos, heads, etc.). Each possible body part is identified and a location from each other is used to determine if it is a feasible person (as well as which person each part belongs to). This will eliminate problems with occlusion of people in a scene.

Pedestrian Following.

The main purpose of this project is to create an algorithm to track a particular person using color stereo cameras. It will be implemented on several different

robotic platforms. The system will be operator initiated through the selection of a specific person to follow by clicking on the person through the human robot interface (from an image provided by one of the two cameras attached to the robotic vehicle). Next, the pedestrian is segmented from the image and blob clustering is performed based on color and disparity. This processed image is used as a template for the next frame. As the person starts to move, the region of movement from one frame to the next is calculated and the segmented image from the previous frame is used as a template to find the location of the pedestrian and matched. A distance from the cameras (0,0,0 world coordinates) to the pedestrian (x,y,z world coordinates) is computed and sent to the mobility process of the robot. The template matching is dynamic since each template changes from each frame. The computed location can be updated every second or every minute, based on the type of following preferred. It will also be designed to work on any GPS waypoint robotic vehicle. The waypoints will be computed by the calculations of the pedestrian locations.

<u>Fused Infrared and Gray Scale Pedestrian Detection/Enhancement.</u>
This project is a joint effort between the HID Lab and the Perception Lab. The Perception Lab's effort is focused on human perception studies on fusion techniques between gray scale and infrared imagery. The HID Lab's focus is on using the same fusion techniques but applying machine intelligence to the problem. The goal of this project is to have the computer detect pedestrians with comparable results recorded by the human studies. An investigation into computer enhancement of the fused imagery will also be performed.

5. Conclusion

Within the next decade robotic vehicles will be introduced into the battlefield in large numbers as a result of FCS. This will dictate a change in doctrine on how the Army fights. Robots and soldiers will be in the field together and need to coexist and function in teams. It is imperative that robotics systems have an error free pedestrian detection system available.

TARDEC's Intelligent System's Human Intent and Detection (HID) Lab is focused on providing a quality pedestrian detection system based on the type of environment it will be used in. The pedestrian detection efforts shown throughout will feed the Intelligence System's Army Technology Objectives (ATOs) such as Armed Robotic Vehicle (ARV) Robotic Technologies (ART) and Human Robot Interface (HRI). These ATOs provide technologies that transition to FCS platforms.

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Points of Contact

Michael Del Rose
U.S.Army TARDEC
AMSRD-TAR-R, MS 264
Warren, MI 48397-5000
mike.delrose@us.army.mil

Philip Frederick
U.S.Army TARDEC
AMSRD-TAR-R, MS 264
Warren, MI 48397-5000
phil.frederic@us.army.mil